The operating policy of DOE's filter testing program, contained in DOE STD 3022-98,[6] calls for testing all HEPA filters intended for environmental protection at a DOE-operated FTF (ORFTF). Delivery of filters to the FTF for QA review is mandatory for all DOE facilities, and this service is also available to the public on a fee basis. When the filter manufacturer's test data are confirmed, the FTF test results are added to the information on the filter case. The test procedures at the FTF call for "penetration and resistance tests," "visual inspection for damage and visible defects," and other "visually verifiable requirements." Except for filters rated at less than 125 cfm, penetration tests are to be conducted at 100 percent and 20 percent of rated airflow capacity, and the maximum penetration of .3-ìm particles at both airflow rates is 0.03 percent, in accordance with DOE STD 3025-99.[7] Penetration tests may be conducted using a monodisperse aerosol and a total light-scattering photometer or a polydisperse aerosol with a single particle counting and sizing instrument. A QA program for the DOE FTF is contained in DOE Standard 3026-99.[8] Specifications for HEPA filters to be used by DOE contractors are contained in DOE STD 3020-97.[9]

8.4 VISUAL INSPECTION

Visual inspection is an integral and vital part of every acceptance or surveillance test. A careful visual examination should be made of each internal and external component prior to installation to verify that the items have been received in satisfactory and serviceable condition. After installation, the system should be checked as part of the acceptance test procedure to make sure that all required items have been properly installed. A suggested checklist is provided in Section 5 of ASME N510,[10] which may be used to verify that system design and construction are in accordance with ASME N509[11] and ASME N511-2001.[12] ASME AG1 also provides guidance for visual inspection in Section 5.0 and Appendix 1, Section AA-5000.[3] Preparation of the proper visual checklist is the most important part of the test procedure. The checklist should cover all major potential problems without further testing, including the relevant items identified in Section 5.0 of ASME N510,[10] and also should incorporate the field observation checklist items listed in Appendix C of ASME N509[11] where applicable. Certain items listed in the recommended checklist in ASME N510[10] are only observable prior to installing the components. Experienced field test personnel should be able to find bank leak paths of a few tenths of a percent by visual examination, as well as many other potential problems not identified by the actual leak test procedures. An example of an excellent field check list used by Los Alamos National Laboratory (LANL) is presented in Appendix A and B, respectively.

8.5 IN-PLACE COMPONENT TESTS AND CRITERIA

System tests fall in two broad categories: (1) prestartup acceptance tests to verify that components have been installed properly and without damage and that the system can operate as intended, and (2) surveillance tests made periodically after the system has been placed in operation to demonstrate its ability to continue performing its intended air cleaning function. Surveillance tests are leak tests of the HEPA filter and adsorber installations. To provide guidance for the preparation of test procedures, details of acceptance and surveillance tests are given in ASME N510,[10] ASME N511,[11] and ASME AG-1.[3] In all cases, tests should be preceded by careful visual inspection, as previously discussed in Section 8.4 above. It is noteworthy to add that a spring-loaded clamping device was developed at the Rocky Flats Environmental Closure Site to provide continual holding of HEPA filters and eliminate the need to re-enter the plenum and retorque installed filters.[39]

8.5.1 ACCEPTANCE TESTING

Acceptance tests also fall into two broad categories: (1) those that relate to the permanent elements of the system, ducts, housing, mounting frames, and location of test ports, and (2) those that verify the installation and condition of the primary air cleaning components (HEPA filters and adsorbers). Acceptance tests of HEPA filter and adsorber installations are identical to the surveillance tests of those elements and are covered in Section 8.6. Tests in the first category include leak tests of ducts, housings, and primary-component mounting frames; airflow capacity and distribution tests; gas residence time tests for systems containing adsorbers; duct-heater tests for systems containing heaters; and air-test aerosol mixing-uniformity tests. The acceptance test program for a particular system may contain any or all of these tests, depending on the nature of the system and its importance (i.e., the potential consequence of a failure of, leakage from, or release from the system).

USNRC regulatory guides recommend the full battery of acceptance tests for engineered safety feature (ESF) systems, and the requirements for testing of safety-related nuclear air treatment system components are covered by USNRC Regulatory Guide 1.52.[13] In addition, requirements for testing of non-safety-related nuclear air treatment system components are covered by USNRC Regulatory Guide 1.140.[14] Neither the ASME N510 standard nor the two regulatory guides are consistent in their requirements, and a coordinated version and further clarification are long overdue. The new 2001 revisions of both regulatory guides incorporate references to AG-1 in an attempt at consistency. While not perfect, they are a big improvement over the previous versions. Lesser systems may not warrant such stringent testing. On the other hand, these tests, which are conducted only once when a new or rebuilt system is accepted, provide an assurance of system reliability that cannot be obtained in any other way. The ASME CONAGT (responsible for ASME N510[15]) recommends that these tests be considered for any high-reliability system.

The original standard for nuclear air cleaning component testing was developed by the American National Standards Committee's N45.8.3 ad hoc group.[15] The first version of "Testing of Nuclear Air Cleaning Systems," (ANSI N510-1975)[42] was later revised to ANSI/ASME N510-1980[1], then ASME N510-1989.[43] This standard was updated by the ASME CONAGT Group, and a final version for acceptance testing was issued as ASME AG-1, Section TA, "Field Testing of Air Treatment Systems." "In-service Testing of Nuclear Air Treatment Systems" was issued as ASME N511.[12] The basic precepts of ASME N510[10]; ASME AG-1, Section TA[3]; and ASME N511[12] are listed below.

- All components (prefilters, mist eliminators, HEPA filters, adsorbers, etc.) are qualified and tested as individual components. Their original efficiency is established, and "as-installed" tests do not require further "efficiency testing." Only the in-place test is conducted to ensure the integrity of components is maintained and that no bypass exists.
- The housing is of the desired strength and integrity, which can be measured by isolating the unit envelope housing and leak testing under the specified pressure differential conditions.
- The framework integrity (framework holding critical components such as HEPA filters and adsorbers) can be measured by using blank off plates and pressure differential leak tests.
- When critical components are installed, the in-place leak test measures only the quality of the installation of the components.

The standard writers assumed that the components are well designed and that pyramiding of the four above-listed precepts will realistically measure the adequacy of the installed operating unit.

For clarity, it must be reiterated that the definition of the "Unit - Air Cleaning Unit" is an assembly of components that together comprise a single subdivision of a complete air cleaning system, including all the components necessary to achieve the air cleaning function of that subdivision. A unit includes a single housing, with the internal components (filters, adsorbers, heaters, instruments, etc.) installed in or on that housing.

Acceptance tests are outlined in Table 1 of ASME N510[10] and in ASME AG-1, Section TA.[3] Before assembly, personnel should assure that all components meet the specified criteria. Typical QA acceptance only assures that paperwork is available. The quality of the results reported in the paperwork is very rarely reviewed. This paperwork should be checked both for original supply and for replacement parts. Before installing components, personnel should perform the following tests.

- Visual Inspection

- Duct Leak Test
- Housing Leak Test
- Mounting Frame Leak Test

During and immediately after installation of components, personnel should perform the following tests.

- Visual Inspection
- Air Flow Capacity and Distribution Test
- Air/Aerosol Mixing Uniformity Test
- In-Place Leak Test HEPA Stage
- Remove Adsorbent and Perform Laboratory Testing (to establish base line carbon efficiency)
- In-Place Leak Test Adsorber Stage
- Duct Damper Bypass Leak Test (if required).

The tests listed in ASME N510,[10] Table 1, include:

- Visual Inspection – Section 5 (to ensure that components are properly installed and are not damaged)
- Duct and Housing Leak and Structural Capability Test – Section 6 (to ensure the installed housing has leakage and structural integrity)
- Mounting Frame Pressure Leak Test – Section 7 (to ensure that no bypasses exist at welds, etc.)
- Airflow Capacity and Distribution Tests – Section 8 (to ensure that desired flows can be achieved with clean and dirty filters, and also that velocities through components are in the narrow range where the components were qualified individually)
- Air Aerosol Mixing Uniformity Test – Section 9 (to ensure the test aerosol injection and sampling ports are located properly to perform testing of the HEPA filter bank or adsorbent stage)
- HEPA Filter Bank In-Place Test – Section 10 (to establish that the HEPA filters are properly installed and were not damaged before or during installation)
- Adsorber Bank In-Place Test – Section 11 (to establish that the adsorbers were properly installed and that there is no major settling and/or channeling of the adsorbent)
- Duct Damper Bypass Test – Section 12 (to qualitatively assess leakage through bypass dampers in the system)
- System Bypass Test – Section 13 (to ensure that all filter banks and potential bypass leakage paths are assessed in the leakage test)
- Air Heater Performance Test – Section 14 (to ensure that the heaters used for humidity control are capable of achieving the desired RH)
- Laboratory Testing of Adsorbent – Section 15 (to quantify the efficiency of the carbon media for its ability to adsorb radioiodines)

Two critical items have to be understood in the use of ANSI N510.[10] First, the standard is considered a test method for air cleaning systems designed according to ASME N509.[11] However, ASME N510[10] was initially issued in 1975, and ASME N509[11] in 1976, years when a large number of U.S. power reactors were already designed and even many later facilities were designed with only with limited adherence to common sense engineering practices or the requirements of ASME N509.[11] The second critical item is the potential for misinterpreting the SCOPE section of ASME N510,[10] which states that it is a "basis for the development of the test programs and detailed acceptance and surveillance test procedures," and "that it be rigorously applied only to systems designed and built to ASME N509."[11]

In spite of this rather clear scope definition, many facilities established their test methodology by either generally claiming that, "testing shall be in accordance with ASME N510,"[10] even when their systems were not designed for it (or according to USNRC Regulatory Guide 1.52[13] or 1.140,[14] which refer to ASME N509[11] and N510[10] requirements). Some never developed a specific test program for each unit and system to modify the basic N510[10] procedures to ensure achievement and maintenance of the desired result (complete system integrity). The treatment of issues related to air cleaning unit and system testing here is based on ASME N510.[10]

If all of the referenced tests are performed sequentially every time and the air flows are well balanced from a specified intake point to a specified discharge point, then the test series may be considered a system test. However, if only parts of it are performed, it is not a system test—only an installed component section test (i.e., a HEPA filter bank or adsorber stage bank test).

8.5.2 DUCT AND HOUSING LEAK TEST

The level of duct and housing leaktightness (and therefore the acceptance criterion for the test) is based on the type of construction and the potential hazard (consequence) of a leak. Recommended maximum permissible leak rates for various duct and housing constructions are given in AG-1, Section TA, "Field Testing of Air Treatment Systems."[3] The designer may specify tighter requirements based on the containment requirements of the system.

Duct leak tests may be conducted by testing the entire ductwork system at one time or by testing one section at a time and blanking off the ends of the section under test. The second method is more practical for larger systems. When segmented, the permissible leak rate for the individual sections is based on the proportionate volume of that section. The apparatus and procedure for leak testing level 1 and 2 ducts are described in the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) High Velocity Duct Construction Standards.[16] Using the described procedures outlined in ASME N510,[10] duct leak tests can also be developed with some modifications. The N510 standard offers two test methods for housing leak test: the Pressure Decay Method, the most convenient for larger duct and housing systems, and the Constant Pressure Method, the most effective for smaller volumes.

Test methods for level 3, 4, and 5 ducts and for housings are described in Section 6 of ANSI N510.[10] If the specified leak tightness cannot be met, leaks are located, repaired, and retested by one of the methods described in Section 6 of ANSI N510.

When performing the unit housing leak test, it is important to follow the normal procedures (door closing, etc.) and thereby avoid creating a once-in-a-lifetime condition that does not resemble normal operating procedures and conditions. The test is supposed to demonstrate that the unit housing will maintain the specified leaktightness during its operating life. Based on experience, this is an unrealistic expectation. There is always some deterioration of door gaskets, or occurrence of sprung doors, damaged threads on closures, and leaks due to maintenance work on the unit. To ensure the leak integrity of the housing is maintained, personnel should perform periodic retesting (every 10 years).

8.5.3 MOUNTING FRAME PRESSURE LEAK TEST

This test is performed to ensure the installed HEPA filter/adsorber mounting frame is installed with no leak paths through the structure. This is considered an optional test because the same evaluation is done after the filters are installed, and an in-place leak test is performed on the bank. However, this test may be useful for determining gross leakage prior to filter installation. Any repairs required must be done before installation of any HEPA filter/adsorber. This test is also the first check for any other leak paths through conduits, drains, etc., which communicate between the upstream and downstream side of a single bank of HEPA filters or adsorber banks. Realistic test performance requires the unit housing leak test to be performed and the specified leak criterion to be met. The acceptance value set in the specifications should always be realistic.

These tests are conducted to verify there are no leaks through the HEPA filter and adsorber mounting frames or through the seal between the mounting frames and the housing. The tests also verify there is no bypassing of the mounting frames through electrical conduits, drains, compressed air connections, and common anterooms of the housing, or other inadvertent leak paths. Familiar sources of leaks are weld cracks and incomplete welds. A properly designed mounting frame should have no penetrations (via conduits, piping, or ducts), and lighting, drain, and other ancillary systems should be designed so that no bypassing of the HEPA filters and adsorbers can occur. Nevertheless, unauthorized modifications are often made in the field. The purpose of this test is to disclose such items, as well as any leaks caused by poor workmanship or shipping damage. The test is recommended for any installation, whether duct and housing leak tests are performed or not, but it is particularly necessary when subsequent in-place tests of the HEPA filter and adsorber stages will be performed using a shrouded method.

This test is conducted by first blanking off all openings for filters and adsorbers and closing or blanking off all openings in the housing, then conducting a soap-bubble or spray test aerosol leak test around all welds and other potential leak paths (as described in Section 7 of ANSI N510).[10] After all leaks have been repaired, individual chambers of the housing should be checked by a pressure leak rate test to verify there are no bypasses that were not disclosed by the leak detection check. It is unnecessary to perform these tests from the upstream side of the mounting frame, and it is quite acceptable to test two mounting frames simultaneously by blanking off the openings of both and pressurizing the space between. Because the mounting frame pressure leak test is a chamber-by-chamber test of the housing, it can replace the need for a housing leak test (Section 8.5.1.1).

8.5.4 AIR FLOW CAPACITY AND DISTRIBUTION TEST

This test is used (1) to verify that the specified volume flow rate of the air can be achieved with the installed fan under actual field conditions at maximum and minimum filter pressure drop and (2) to verify that the airflow distribution across each HEPA filter or adsorber stage is within the specified uniformity at the designed volumetric flow rates. ASME N509[11] and N510[10] require an airflow distribution of ±10 percent maximum deviation from design flow. This value is not well correlated to the assumption of USNRC Regulatory Guide 1.52[13] and the radioiodine test methods specified in ASTM D3803[44]. The variation of ±10 percent in velocity through the adsorbent bed results in a very high variation of the methyl iodide-131 removal efficiency. Recent parametric testing for radioiodine removal efficiency showed that even the ±4 percent flow variation permitted in ASTM D3803[44] is too high to obtain good reproducibility. To ensure proper correlation of the results used to justify the potential performance of the adsorber stage, the volumetric flow through the adsorber stage should result in not less than a 0.25-sec residence time (for a 2-in.-thick bed). Therefore, a design flow of +0, -20 percent is much more realistic than the design of ±10 percent permitted by ASME N509[11] and N510.[10] Similarly, ASTM D3803[44] should require a velocity corresponding to 0.25-sec residence time and +4, -0 percent to achieve adequate reproducibility and to err on the conservative side. The procedure for airflow capacity testing recommends making pitot tube traverses of the ducts. However, the following values must also be considered.

Duct size	Number of Readings	Precision of Measurements
<150 mm	1	±20 percent
400 < 150 mm	4	±12 percent
950 < 400 mm	8	±10 percent
>950 mm	12	±5 percent

ASME N510[10] is unclear about how the precision of the measurement should be used to achieve the ±10 percent specified flow capacity. Due to the convoluted design of the air cleaning system inlet and outlet ducts, it is often impossible to find an adequate duct location that is, as required by the American Conference of Governmental Industrial Hygienists (ACGIH) *Industrial Ventilation Handbook*, [40] ten duct diameters downstream and five duct diameters upstream of points where turbulence is induced in the airflow (e.g., elbows and junctions), which further subtracts from the precision of the velocity measurements. The location where the acceptance airflow capacity test was performed should be tagged (indicating the date, method used, etc.) to ensure that future tests are made at the identical location. LLNL places test fittings at the locations used. The test fittings are necessarily about an inch in diameter to permit turning equipment 90 degrees after insertion and are capped. This makes them both durable and easier to find. ASME N510, Table 1,[10] requires this measurement to be an acceptance test only. However, experience shows that changes in airflow capacity occur in intervals as short as 18 months due to damper adjustments, pressure conditions at inlet points, duct disassembly and reassembly either upstream or downstream of the unit, etc. Therefore, this measurement should be a routine surveillance test item each time a unit or system surveillance test is made.

The actual text of ASME N510, Section 8,[10] indicates via a note that only the air distribution test is an acceptance test (presuming the airflow capacity is both an acceptance and a surveillance test, as it should be). This test has to be performed for 15 min to show steady-state conditions. The airflow distribution test leaving the HEPA filter banks and the adsorber banks is required by ASME N510.[10] In many existing units, there is inadequate space to perform the test downstream of the banks. Any test performed on the entry side of these banks must be more conservative for the HEPA filter banks because of the flow-straightening characteristics of HEPA filters. Therefore, if such a test meets the criteria, it should be acceptable. [It is important to note that the currently permissible separate airflow distribution uniformity of ±20 percent on top of a ±10 percent airflow capacity and a potential test error of ±10 percent results in permissible residence times in the adsorber section that are far less than might be presumed from the iodine-131 decontamination factor used to establish the Technical Specifications of the facility.]

8.5.5 AIR-AEROSOL MIXING UNIFORMITY TEST

The purpose of this test is to establish the adequacy of the test aerosol injection, upstream sampling port, and downstream sampling port locations.

No safety credit can be claimed for HEPA filters or adsorbers that are not tested regularly to verify they continue to meet performance requirements. Although individual filter units and adsorber cells are tested by the manufacturer, in-place testing after installation is essential because of the damage and deterioration that can take place during shipping, handling, installation, and service. Therefore, an important phase of acceptance testing is verification that HEPA filter and adsorber installations can be tested satisfactorily. The design of many older systems permitted an acceptance test of the HEPA filters, but made testing after the system began operation nearly impossible, particularly in cases where the system was contaminated. In addition, some systems were designed to be so cramped that quantitative testing of the kind specified in ASME N510[10] was impossible due to poor airflow distribution or ducts that had unreachable portions of cross-sectional area. Such designs are not acceptable in high-reliability applications.

This test method described here includes tests to establish the adequacy of the test aerosol injection and upstream sampling port locations, but does not generate data reflecting the adequacy of the downstream sampling port location. Undoubtedly, the test should be a prerequisite for performance of any in-place test of a HEPA filter bank and adsorber bank stage. The verified locations of injection and upstream sample ports should be documented, and the locations should be tagged to indicate the date, method used, etc., as well as the tests to be conducted. All other ports found to be unsatisfactory should be tagged to prevent later accidental use of incorrect injection or sampling ports.

The aerosol injection point for the first HEPA bank and the adsorber stage should always be ahead of any unit or system bypass line, and the downstream sampling point for the second stage HEPA filter bank and for challenge vapor should always be downstream of the return of the bypass line into the main duct.

In-place tests should be made by introducing a test aerosol upstream of the bank to be tested. The concentrations of test aerosol upstream and downstream (upstream concentration is considered 100 percent) should then be determined, and penetration should be calculated from the ratio of concentrations. The reliability of this test is determined by (1) the ability to properly introduce the test aerosol and obtain representative samples and (2) the availability of physical access to the banks being tested. The first can be verified by an air-aerosol mixing test. This test should be made once, at the time of acceptance testing, and its satisfactory completion is required before both acceptance and future surveillance in-place testing of HEPA filters and adsorbers.

Good testability requires provision of permanent test aerosol injection and sample ports or other planned and pre-established means for injecting the test aerosol and for taking reliable, well-mixed samples. Details of the air-aerosol mixing test are described in Section 9 of ANSI N510.[10] It is essential that the air and test aerosol mixture challenge to the filters (adsorbers) is thoroughly mixed so that the concentrations entering all points of the filters, including the upstream and downstream sample points, are essentially uniform. Adequate mixing upstream usually can be obtained by introducing the test aerosol at least ten duct diameters upstream of the filters or adsorbers, or by introducing it upstream of the baffles or turning vanes in the duct. When neither of these methods is practical, a Stairmand disk[17] located four to six duct diameters upstream will provide satisfactory mixing. A Stairmand disk is a plate with the same geometric shape as the duct section that blocks the central half of the duct area. Air flowing past the disk creates vortices on the leeward side that compel turbulent and thorough mixing. The disk is placed into the duct for testing. At other times it is either removed, swung out of the way, or turned on a pivot so the long axis is parallel to the direction of flow. When duct arrangement makes it necessary to introduce the test aerosol directly into the filter housing, a design such as that discussed under multistage housings (Section 8.6.5) may be required. Extraction of the downstream sample at a point several duct diameters downstream of the fan will usually provide a well-mixed sample. Fan-shaft leakage should be considered in sampling downstream of the fan. Since leakage at the shaft will be in-leakage, sufficient air to excessively dilute the downstream sample can be drawn in if the shaft annulus is large (yielding a low downstream concentration reading), or dust may be drawn into the fan to provide a high downstream reading (which may be particularly prevalent during construction). Application of a shaft seal, or at least a temporary seal, is recommended during testing. If this is not practical, a photometer leak reading should be taken with and without the aerosol generator "on" to establish shaft seal leakage.

The second aspect of testability—access—requires space for personnel and equipment; space to manipulate equipment without damaging filters or creating hazards for personnel; passages for getting personnel and equipment where they are needed; means of providing power (electrical, compressed air) to the equipment; access to both faces of the filters and adsorbers; adequate lighting; viewports; and other features that facilitate safe testing. Space also will be needed later during filter replacement for (1) temporary storage of removed filters/adsorbers and their replacements, (2) crew movements required to effect the change (such as bagging in/out), (3) placement of tools, and (4) personnel, including both the filter technicians and any associated safety staff or radiation monitoring technicians. Consideration should be given to making the area easy to decontaminate if necessary by making the floor and area as free of cracks, crevices, and hard to clean/reach places as practical.

8.5.6 DUCT DAMPER BYPASS TEST

Section 12 of ASME N510[10] requires testing of potential bypass leakage paths to ensure that radioactive gases or particulates do not escape treatment through the HEPA and/or adsorber banks. This test allows testing of the potential leak path during the test aerosol or Halide test on the HEPA/adsorber banks, assuming the injection sample ports are located such that the potential bypass is included in the test envelope. Otherwise, the bypass (damper) may be tested using conventional pressure-testing techniques.

8.5.7 SYSTEM BYPASS TEST

Section 13 of ASME N510[10] requires challenging of all potential bypass leakage paths and all portions of the nuclear air treatment system (including the housing stages) during the test sequence. All potential bypass leakage paths around the HEPA/adsorber banks must be included as a single overall leak test of the sum of the individual tests on the separate banks. In dealing with a series of HEPA or adsorber banks, each bank must be tested individually to ensure that contaminated air does not bypass the filter banks or escape treatment.

8.5.8 DUCT HEATER PERFORMANCE TEST

Section 14 of ASME N510[10] requires the humidity control system for the carbon adsorber bank (which prevents water buildup on the carbon) to be tested to ensure satisfactory performance. For example, the voltage always has to be checked to make ammeter readings meaningful. The temperature should be checked sufficiently upstream and downstream of the heater to ensure an adequate rise in air temperature. The readings obtained also should be evaluated by a cognizant individual to ensure the desired RH can be achieved with the potential minimum and maximum environmental temperatures in the inlet stream.

8.6 SURVEILLANCE TESTING

There are three types of surveillance tests: (1) in-place leak tests of HEPA filter stages using an accepted test aerosol, (2) in-place leak tests of adsorber stages using a slightly adsorbable gas such as the fluorocarbon Refrigerant-11, and (3) laboratory tests of samples of adsorbent withdrawn from the system to establish its remaining adsorption capacity. These tests are also employed as part of the acceptance procedure for new installations, with the exception that laboratory tests are made on samples of adsorbent taken from batch material as furnished.

Surveillance tests of HEPA filter and adsorber systems should be made at regular intervals after installation to detect deterioration and leaks that may develop under service conditions. Regular in-place testing of standby systems is necessary because deterioration can take place even when the systems are not being operated. Aside from component damage, frequently discovered causes of failure to meet in-place test requirements include loose clamping bolts; inadequate clamping devices; foreign material trapped between gaskets and mounting frames, rough or warped mounting frame surfaces; cracked welds; unwelded joints in mounting frames; ground settlement; incorrectly installed components (e.g., HEPA filters installed with horizontal pleats); inadequate seals between mounting frames and housings; poorly designed mounting frames; and bypasses through or around conduits, ducts, or pipes that penetrate or bypass the mounting frames.

8.6.1 IN-PLACE LEAK TEST, HEPA FILTER BANKS

Section 8 and 9 of ASME N510[10] are prerequisites for the HEPA filter in-place leak test. In cases where there are multiple series or parallel HEPA banks and associated bypass leakage paths, the guidance outlined in Section 13 of ASME N510, "System Bypass Test," should be followed. The proper procedure to be used with dual HEPA filter banks is to introduce a test aerosol at the predetermined, qualified location (the test port) upstream of the first bank, and then determine a downstream reading of the first bank between the two filters (the second bank will block any leakage). If this determination is satisfactory, then while injecting at a point (or through a manifold) upstream of the second HEPA filter bank (between the banks), readings should be taken downstream of the second HEPA filter bank, preferably downstream of the fan. This test should be performed every time on every unit where two HEPA banks in series are installed.

There are three major types of in-place testing methods. The first test method uses a light-scattering photometer with a polydispersed aerosol. The second method uses a shroud and/or scanning test technique, and the third uses a laser spectrometer in lieu of the forward light-scattering photometer. Due to differences in the designs of HEPA filter plenums throughout the DOE complex, as well as corresponding differences in testing techniques, the Defense Nuclear Facilities Safety Board recognized a need to standardize methods for in-place testing at DOE sites. To address this need, a conference was held at the DOE Savannah River Site (SRS) to exchange information about the sharing of in-place testing technology among DOE contractors.[18] The conference concluded that all DOE sites basically used the same type of penetrometer, with the exception of LANL, which uses the laser spectrometer. In-place tests of HEPA filter installations are made with a polydispersed test aerosol consisting of droplets with a light-scattering number mean diameter (NMD) of 0.7 μm and a size range of approximately 0.1 to 3.0 μm.[10] The test aerosol used for efficiency testing by manufacturers and DOE's Filter Test Facility (ORFTF) is a monodispersed aerosol with a light-scattering NMD of 0.3 ± 0.03 μm. The in-place test is made by challenging the upstream side of the filter or filter bank with test aerosol smoke, then measuring and comparing (using a light-scattering photometer) the test aerosol concentration in samples of downstream (filtered) and upstream (unfiltered) air (**FIGURE 8.5**). If the system